Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE

JOURNAL OF GEOLOGY

JANUARY-FEBRUARY, 1903

THE OSTEOLOGY OF *EMBOLOPHORUS DOLLOVIANUS*, COPE, WITH AN ATTEMPTED RESTORATION.

THE Pelycosaurian fauna of the Permian beds of Texas has been described from fragmentary material in very large measure, from fragments of the skull, from isolated portions of the vertebral column, and from separate limb bones; rarely is any large portion of one animal found preserved. The result has been the almost inevitable description of different portions of the skeleton of forms belonging to the same genus and species under different names. This fact has been very apparent in the attempt to locate the correct taxonomic position of the very complete specimen described below, but at the same time it has made apparent the compactness and coherence of the family *Clepsydropsidae* in a most striking manner.

In the collection of the University of Chicago is a specimen, No. 114, of a Pelycosaurian in which a very large portion of the skeleton is represented, warranting an attempt at a description of the complete osteology. The bones were incased in the peculiarly refractory cement of iron and sand which is common on the bones in this locality, and this has rendered the preparation of the skeleton and its study a matter of long time. The specimen was discovered in slightly inclined strata with the head downward and the tail exposed, so the forequarters and skull were well preserved.

The type genus and species, *Embolophorus fritillus*, was described in 1878[1] as follows:

This form reposes on some dorsal vertebræ with intercentra and ribs in place, which display some interesting characters. The neural arch is co-ossified, and the zygapophyses and diapophyses are well developed; the latter not elongate, and standing on the base of the neural arch. The centra are notochordal. The intercentra are narrowed and transversely elongate. The ribs are two-headed; the capitulum is received into a fossa on the posterior border of the intercentrum in advance of the vertebra which supports the diapophysis, to which the tuberculum is attached.

The curious mode of articulation I have not observed in the species of the genera heretofore described, unless the forms of some of the intercentra of *Clepsydrops limbatus* indicate it. If so, that species must be removed to *Embolophorus*.

Char. spef.—Centra with circular section at all points and contracted in at the middle. No carinæ or grooves. The intercentra project beyond the edges of the centra, giving the column the appearance of supporting annular ridges. Their lateral angles extend upward nearly to the base of the neural arch. The diapophyses are short and directed upward and forward; their extremities are concave. The zygapophyses are large and their faces are nearly hortizontal. The size of this species is small, little exceeding that of *Bolosaurus striatus*.

MEASUREMENTS.

Length of a centrum with an intercentrum attached		0.0056^{m}
Length of a centrum		0.0040
Diameter of a centrum,	vertical	0.0035
	horizontal	0.0035
Expanse of diapohyses		0.0080
Expanse of heads of rib		0.0035
Elevation to summit of neural canal		0.0045

Later, in 1884,[2] Cope described other features of *Embolophorus:*

The articulation of the ribs in Embolophorus.—The ribs of the Theromorpha are two-headed. While the tubercular articulation has the usual position at the extremity of the diapophysis, the capitular is not distinctly, or is but partially indicated, on the anterior edge of the centrum, in Clepsydrops and Dimetrodon. In Embolophorus, as I showed in 1869 [misprint for 1878], the capitular articulation is distinctly to the intercentrum. A second and larger species of that genus, recently come to hand, displays this character in a striking degree, since the intercentrum possesses on each side a short process with a concave articular facet for the head of the ribs. From the slight corresponding contact with the intercentrum seen in Dimetrodon and the other genera, there can be little doubt that this is the true homology of the ribs in the Theromorpha.

---

[1] "Description of Extinct Batrachia and Reptilia from the Permian Formation of Texas," *Proc. Am. Phil. Soc.*, Vol. XVII, pp. 518, 519.

[2] "Fifth Contribution to the Knowledge of the Fauna of the Permian Formation of Texas and the Indian Territory," *ibid.*, Vol. XXII, p. 43.

These remarks were accompanied by a figure of the vertebra of *Embolophorus*, but no name was given to the new genus.

In 1886,[1] the name *E. dollovianus* is proposed for this last species without further description.

In 1890,[2] Lydekker lists this genus as present in the collections of the British Museum and presents figures of dorsal vertebræ. The specific name is respelled as *dolloverianus*.

From a careful comparison of the type material now preserved in the American Museum of Natural History in New York city, it seems to me that there is little doubt that the species *E. dollovianus* is very much closer to the genus *Dimetrodon* than to the type of *Embolophorus*, and that it must eventually be placed there where the material is better known.

The specimen described below is nearly anatomically complete, the only parts lacking being the ribs, the posterior foot, and the ends of the dorsal spines, with, probably, a few dorsal vertebræ. The right side of the skull is nearly perfect as far back as the posterior edge of the orbit, and the bones are preserved in their natural relations; the weak temporal arches are destroyed, but the articular portion of the suspensorium with the faces for the lower jaw attachment are preserved. The basicranium is separate, as in most specimens of the *Pelycosauria*, but both this and the greater part of the lower jaws are preserved. The bones of the palatal region are badly disturbed and flattened against the inner side of those of the facial region, so that their position cannot be made out further than that they were much as in the specimen of *Dimetrodon* previously described by the author (1). The bones of the shoulder girdle, the clavicles, and the inter-clavicle, a complete fore-limb with the fore foot, of the left side with part of the fore limb of the right side, the pelvis nearly perfect on both sides, and parts of the bones of the posterior limb are all preserved. Thirty-five vertebræ, beginning with the atlas and terminating with several caudals, represent the vertebral column; it is possible that the column is not complete, but, considering the series and comparing it with Cope's published figure of the vertebral column of the *Dimetrodon*[1] it seems that only the end of the tail and possibly a few anterior dorsals are missing. The figure given by Cope shows the column complete to the second sacral. The dependent portion figured as a part of the attached pelvis on one of the vertebræ is the rib of the first sacral, such as is shown in Figs. 20 and 21, but covered by a portion of the matrix. The peculiar shortening of the lumbar vertebræ is evidently just beginning. There are twenty-five presacrals figured by Cope, but there is a break between the twentieth and twenty-first; there are twenty-seven in the present specimen. From the seeming necessity of proportions and because of the uncertainty as to the correct number, I have added four vertebræ in the anterior dorsal region, making the total thirty-two. This may be too many. The numbers given to the vertebræ in the following descriptions are such as indicate their position in the accompanying restoration, and are arbitrary in that the vertebræ were not all discovered in series, but have been located by their anatomical peculiarities. Beginning with the seventh presacral, the series is complete and was found in position to the second caudal.

---

[1] "Systematic Catalogue of Species of Vertebrata Found in the Beds of the Permian Epoch in North America, with Notes and Descriptions," *ibid.*, Vol. XVI.

[2] "*Catalogue of the Fossil Reptilia and Amphibia in the British Museum*, Part IV, pp. 109, 110.

The skull.—The individual bones of the skull show such slight differences from the bones of the skull of *Dimetrodon incisivus* already described by the author (1) that it is unnecessary to repeat the descriptions. In Fig. 1 is given a side view of the skull, showing the bones in their natural positions; the bones are so slender and the matrix so hard that it has been impossible to remove it all from the bones; in consequence the drawings have been made somewhat diagrammatic, but this has been done only so far as necessary to eliminate the matrix; the relative positions of the bones, and even their distortion, has been preserved. The skull is broken on the mid-line, and the top, which was originally quite flat, has been turned up so that the bones appear in the same plane as the bones of the face. The prominent outer process of the pterygoid bone, which abuts against the inner side of the lower jaw, appears at the lower posterior angle of the skull, and to its posterior edge is attached the articular bone of the lower jaw in an inverted position. The lower jaw is distinct from the mass containing the skull, but in the figure is placed in the correct position.

---

[1] *Proc. Am. Phil. Soc.*, August, 1880, Figs. 3 and 3*a*, Pl. VI.

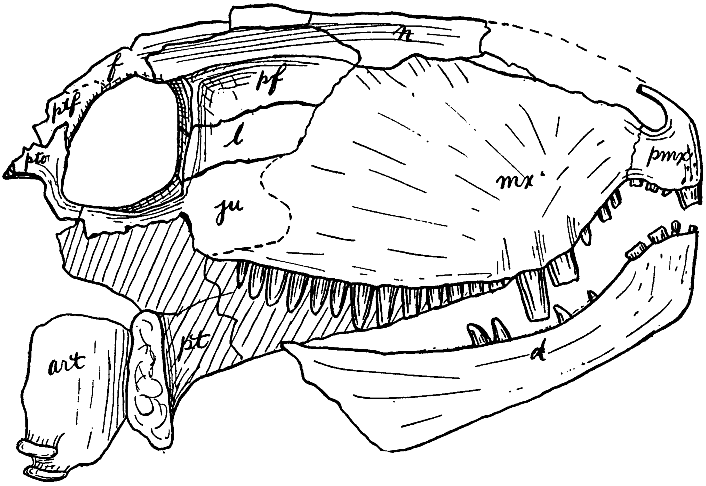

FIG. 1.—Anterior portion of the skull; left side. ⅓ natural size.

Noticeable is the large size of the orbit, with its prominent border all around, and its elevated position at the posterior angle of the skull. There is but a single large canine tooth in the upper jaw where *Dimetrodon* has two, but this is, perhaps, of no great taxonomic value, as in forms with successional teeth it is very possible that one may be lost before the other is far enough developed to appear. Neglecting this difference, the number of teeth in the upper jaw is the same (seventeen) in both genera. In Fig. 2 is shown a restoration of the skull of the *Pelycosauria* published in 1899 (1). A comparison with Fig. 1 will show that this restoration is in all essentials correct, at least as regards the side and top. Such structures of the base of the

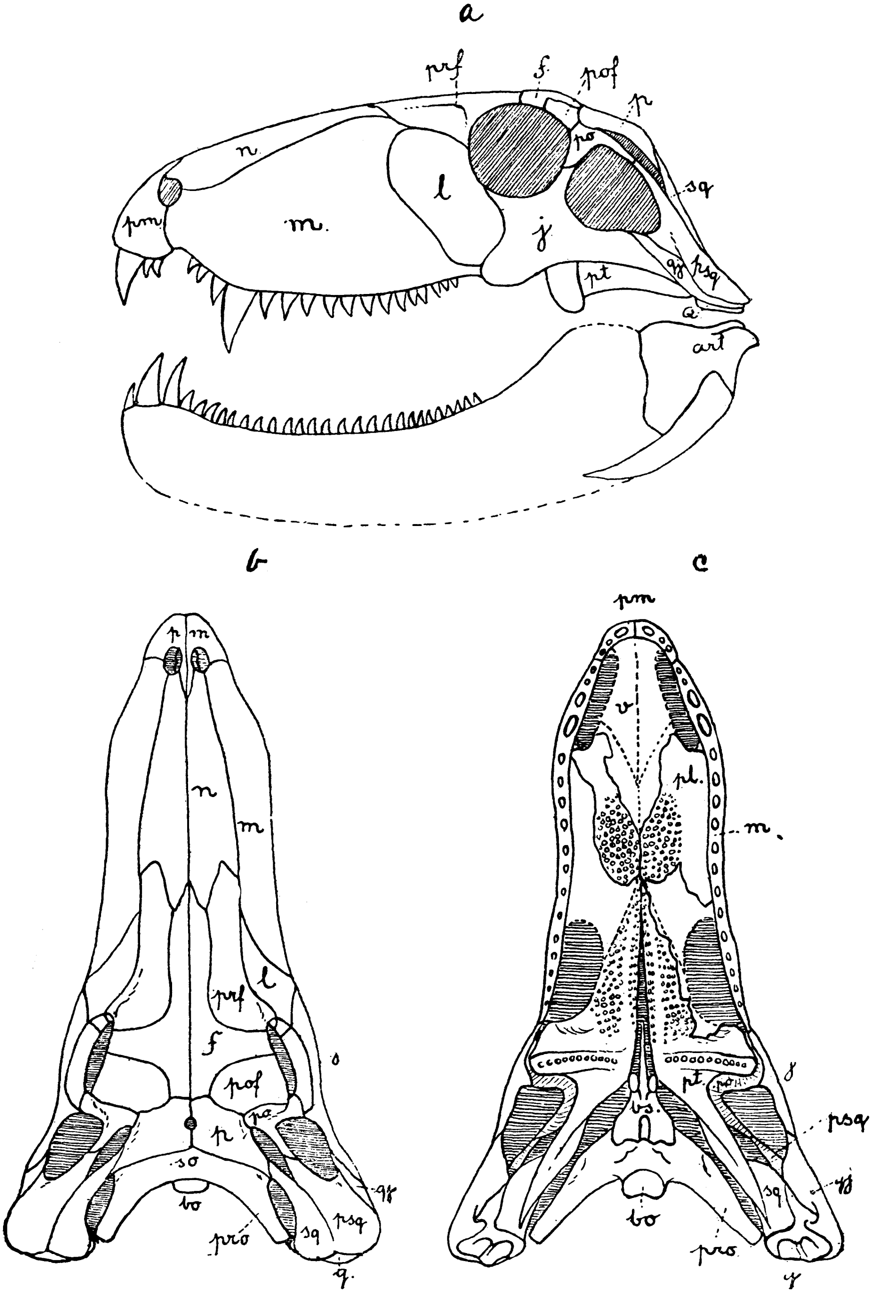

FIG. 2.—Restoration of the skull of the Pelycosauria; *a*, from the side; *b*, from above; *c*, from below.

skull as are preserved also go to show the correctness of the restoration. The basi-cranium is separate from the rest of the skull and shows but few differences from the basi-sphenoid and basi-occipital figured in the description of *Dimetrodon* (1), Pl. I, Figs. 11-14. The bones are somewhat smaller and a little broader in proportion than in *Dimetrodon.*

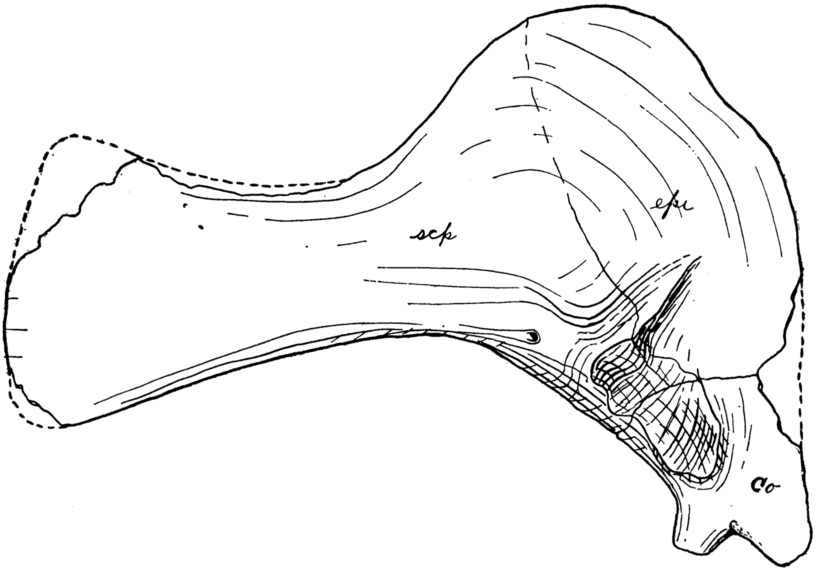

FIG. 3.—United scapula, coracoid, and epicoracoid, *scp*, scapula; *co*, coracoid *epi*, epicoracoid. ⅓ natural size.

MEASUREMENTS OF THE SKULL.

Length of skull from anterior end of nose to posterior edge of orbit	0.225^{m}
Height from just back of last tooth to top of skull	0.080
Antero-posterior and vertical diameters of orbit	0.050
Greatest height of side of skull	0.100

The shoulder girdle.—The left side of the shoulder girdle is preserved almost without distortion, so that it is possible to make out the natural curvature of the structure. In Fig. 3 are shown the united scapula, coracoid, and epicoracoid; the true length of the scapula is not shown because of the foreshortening due to the curvature, but in Fig. 4 are shown the scapula and epicoracoid in profile, showing the true length and the curvature. The coracoid remains free from the scapula through life, but the suture between the scapula and epicoracoid is closed near the outer edges of the bones. The posterior (upper) edge of the cotyloid cavity is formed by a very strong ridge or process of bone which extends out somewhat, upon the epicoracoid. At the base of this ridge the epicoracoid is perforated by a large foramen, and just posterior to the ridge the shaft of the scapula is penetrated obliquely from behind forward by a somewhat smaller foramen. The epicoracoid is very thin, and the greater portion of the scapula is also thin and expanded, but the region near the cotyloid cavity is thicker and very strong.

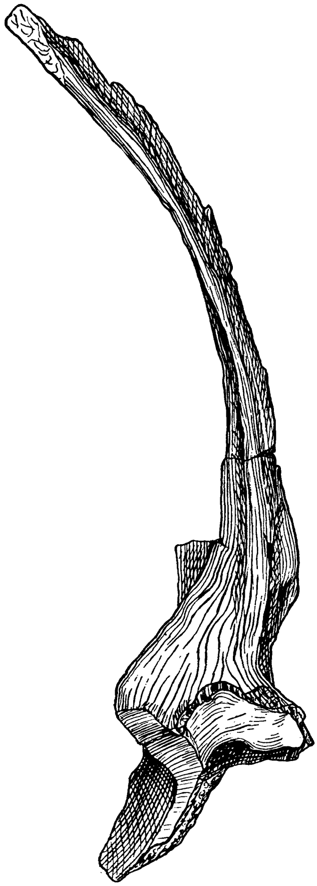

FIG. 4.—Side view of the scapula and epicoracoid. ⅓ natural size.

MEASUREMENTS OF THE SHOULDER GIRDLE.

Length of the scapula - -	0.330–40^{m}
Width across the scapula and epicoracoid opposite the cotyloid cavity	0.120

The clavicle lies in nearly the natural position on the scapula and epicoracoids. It is a peculiarly shaped bone, with the inner ends much expanded and very thin, and the inner edge almost straight. The distal ends are very slender and rod-like and contract to a point which is marked with strong striations. Near the middle of the posterior edge is a rugose process for ligamentous attachment. Fig. 5 shows the clavicle of the right side.

The interclavicle is less well preserved than the other bones of the shoulder girdle, but the size and form are easily made out. There is a long and slender median process which projected posteriorly and is well preserved; the anterior end was thinner and much expanded; the edges are broken, but by comparison with the figure of the interclavicle published by Cope (2), Pl. III, Fig. 5, it would seem that there were strong radial processes. The length of the bone was about 0.31–32^{m}, and the width of the expanded exterior end about 0.120^{m}.

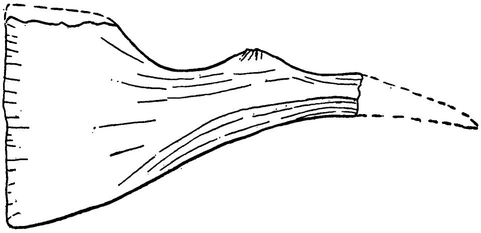

FIG. 5.—Clavicle of the right side, lower view. ⅓ natural size.

In Fig. 6 is shown in diagrammatic manner the shoulder girdle with bones in their proper positions.

The fore limb.—The humerus and radius conform very closely in size and shape with the same bones of *Dimetrodon;* see (1), Pl. III, Figs. 32 and 33. The ulna is represented by the proximal end only, but this is quite different from the ulna of *Dimetrodon.* Compare Fig. 7 with (1), Pl. III, Figs. 34 and 35. The olecranon fossa is more widely open, and the whole bone is more clumsy and less finely moulded—a remark which may apply to all the bones of the skeleton in a general way.

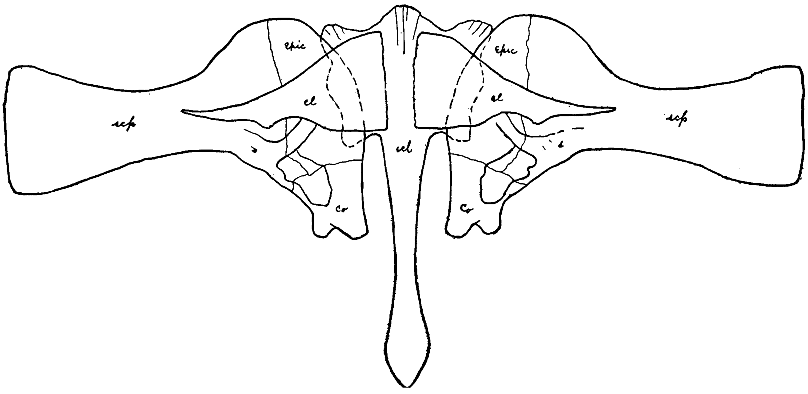

FIG. 6.—Diagram of the shoulder girdle seen from below, *scp*, scapula; *co*, coracoid; *epi*, epicoracoid; *cl*, clavicle; *intc*, interclavicle.

Length of the humerus - - - - - - - -	0.191^{m}
Width lower end humerus - - - - - - - -	0.103

The front foot of the left side is nearly perfectly preserved, a few of the phalanges only being lost. Unfortunately the bones were not all preserved in position, so that it is impossible to give the position of all the elements with certainty; the bones of uncertain position are those marked carpals 3, 4 and 5, and *centrale* and digits 3, 4 and 5. The other bones and digits 1 and 2 are in the position in which they were found, which is seemingly the correct one. Most notable is the small size of the first digit and its possible wide diversion from the other digits in life. It lies attached to the side of the metacarpal of the second digit and turned at right angles to the other digits, so that it appears in profile when the others are seen from the top or bottom. All the digits terminate in claws of relatively great size, and that of the reduced first digit is as large or larger, absolutely, than those of the other digits. There must have been considerable cartilage in the carpus, for, although the bones have been separated and carefully cleaned, it is impossible to articulate the elements with any accuracy. Fig. 8 shows the most probable position of the bones.

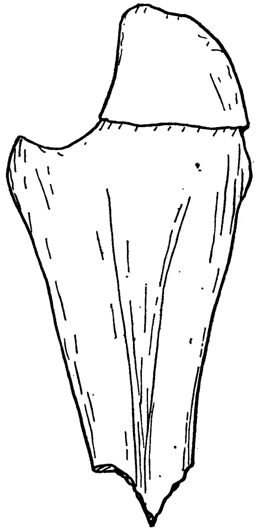

FIG. 7.—Upper portion of the ulna of the left side. ⅔ natural size.

The pelvic girdle.—The pelvis is nearly perfect. The two sides are preserved, so that the missing parts of one side are supplied by the other. The only point of uncertainty is the exact shape of the thin lower edges of the ischium and portions of the edges of the pubis and ilium. As shown in Fig. 9, the three bones meet in the acetabular cavity and are separate through life. The ilium ends anteriorly in an abrupt elevated crest and posteriorly is continued as a slender rod. The ischium is a broad and very thin plate, nearly semicircular in outline; the bones of the two sides evidently met in a ventral symphasis. The acetabular edge of the ischium is very strong and prominent, and looks rather forward and upward than straight upward. This is similar to the condition found in the *Crocodilia* and other forms where the belly is carried very low between the legs. The pubis lies nearly parallel to the axis of the body.

MEASUREMENTS OF THE PELVIS.

Greatest length of ilium - - - - - - - - -	0.150^{m}
Length articular face in the cotyloid cavity - - - -	0.061
Width articular face in the cotyloid cavity - - - -	0.040
Greatest length of the pubis - - - - - - - -	0.121
Length of distal edge of the ischium - - - - - -	0.155

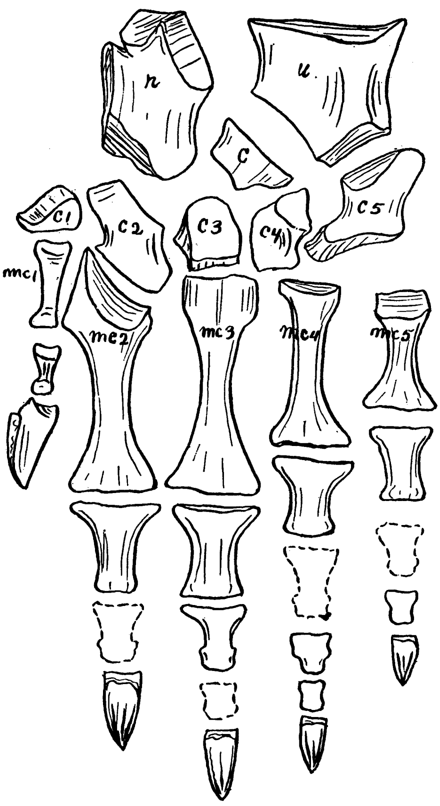

FIG. 8.—Front foot from the upper surface. ⅔ natural size. *r*, radiale; *u*, ulnare; *c*, centrale; *1–5*, carpals one to five; *mc–mc 5*, metacarpals one to five. ⅔ natural size.

The posterior limb.—The posterior limb is represented by the distal end of the femur and the proximal end of the tibia. The femur is very badly preserved. The whole outer shell of bone is scaled off so that what remains is practically a cast of the interior cavity and of the cancelous tissue of the condyles; but it appears that it is very different from the femur of *Dimetrodon*, (1) Pl. III, Figs. 36 and 37. The condyles are less well separated and lie both near the distal end of the bone instead of one at the side; the whole appearance is of a lower type.

From all appearances of the skeleton the posterior portion of the animal seems to have been somewhat weaker than the anterior.

The vertebral column.—The most notable feature in the skeleton is the wide diversity in the form of the elements of the vertebral column. In the cervicals and lumbars the neural arch is co-ossified with the centrum and in the dorsals it is free. The ribs of the cervicals and anterior dorsals are united by the tuberculum to the transverse process and by the capitulum to a process of the preceding intercentrum, but in the lumbars, caudals, and posterior dorsals there is no process on the intercentrum for the capitulum of the rib which is attached to edge of the centrum. The intercentra change remarkably through the series; in the anterior portion of the column they have considerable vertical height and prominent lateral processes for the capitula of the ribs; in the posterior part of the series they become shallower and wider in an antero-posterior direction and lose all trace of the process for the ribs in the lumbars and even in the posterior dorsals (?). In the cervicals, the dorsals, and the anterior caudals there is a prominent facet on the lower portion of the anterior face of the centrum for attachment of the intercentrum. This is absent on the lumbars and sacrals. The anterior and posterior zygapophyses change from broad in the cervicals to narrow in the dorsals, and broad in the lumbars and caudals again; in the same order the articular faces of the zygapophyses change from horizontal to oblique and back to horizontal, so that the faces of the post-zygapophyses of the dorsals look out as well as downward, and of the pre-

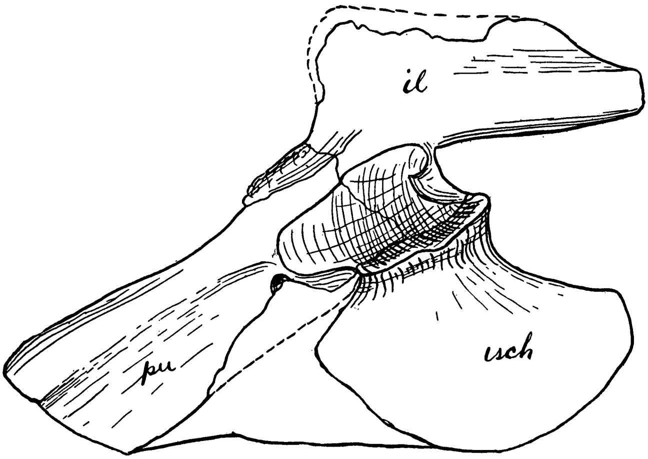

FIG. 9.—Pelvis from the left side. ⅓ natural size.

zygapophyses in as well as up. The bottom line of the centrum in the cervicals and dorsals has a prominent and very thin keel, while this is absent in the posterior lumbars and the sacrals. All these are characters which have been used to define different genera and species, and their union in one form goes to show how close are the different genera of the family *Clepsydropsidae* and how difficult it is to identify forms from isolated vertebræ.

The atlas.—The first cervical is represented by a centrum only; there was probably a very rudimentary and loosely attached neural arch which has disappeared. The first intercentrum, between the atlas and condyle, is not preserved. That such an element did exist is shown by its presence in *Dimetrodon* (1), Pl. II, Fig. 20. The second intercentrum, between atlas and axis, is large and presents a deeply concave face for the posterior face of the atlas. On either side of the intercentrum are strong posteriorly projecting processes for articulation with the cervical rib. In the collection of the University of Chicago there are specimens of the atlas of *Pelycosauria* with the pre-atlas inter centrum strongly attached to the atlas by co-ossification (Fig. 10 *a* and *b*).

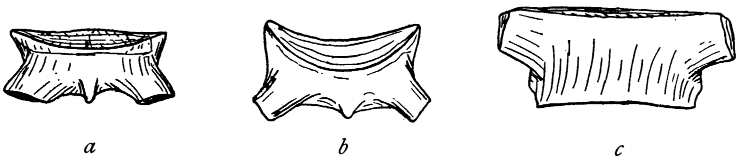

FIG. 10.—*a*, second intercentrum from below; *b*, same from the anterior face; *c* an intercentrum from the posterior portion of the dorsal series. Natural size.

MEASUREMENTS OF THE SECOND INTERCENTRUM.

Greatest breadth - - - - - - - - - -	0.027^{m}
Antero-posterior length on mid-line of lower surface - -	0.012

The *axis* (Fig. 11) has a strong neural spine, with considerable antero-posterior extent; in the last respect it differs quite markedly from *Dimetrodon* where the spine is rather thick and not expanded in the antero-posterior diameter to such an extent,

(1) Pl. II, Fig. 20. The posterior edge of the spine is much thicker than the anterior and is quite flat; the upper end shows a broad surface, smooth and slightly concave, probably for ligmentous attachment. On the anterior edge there are two small areas very similar to the one on the top of the spine. The anterior edge of the neural spine overlapped the centrum of the atlas so that the zygapophyses at the point of contact were weak, if developed at all. There is no trace of the sutural connection between the spine and the neural arch, though such a connection did undoubtedly exist in the youth of the animal. There is no pronounced keel on the lower surface of the centrum, but the whole body of the vertebræ slants obliquely backward, so that the posterior face of the centrum is much lower than the anterior. The transverse process is attached to the base of the neural arch and the upper portion of the centrum; it curves sharply outward and downward. The distal end of the transverse process is lost, but it evidently reached as far down as the lower line of the centrum. The post-zygapophyses are well developed, and the articular faces are horizontal; the region of the pre-zygapophyses is somewhat injured, but enough remains to show that the processes, if present, were small. The upper half of the centrum only, is occupied by the notochordal canal, so that the notochordal funnel of the anterior face occupies the upper portion of the face, the lower half of the face is occupied by the facet for the intercentrum; this is shown in profile in the figure.

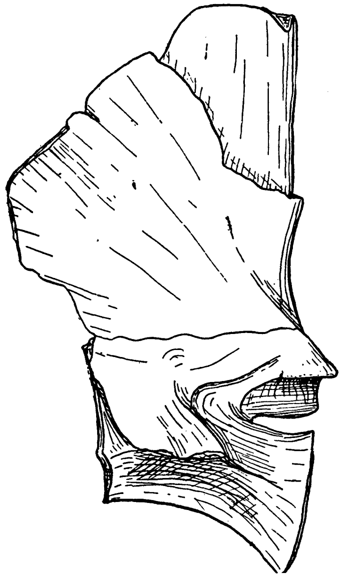

FIG. 11.—Axis. ⅔ natural size.

MEASUREMENTS OF AXIS.

Length along bottom line of centrum - - - - - -	0.038 m
Distance from top of spine to lower line of the posterior face of the centrum - - - - - - - - - -	0.113
Greatest width of spine - - - - - - - - - -	0.054
Width of the posterior zygapophyses - - - - - -	0.032

The spine of the *third cervical* (Fig. 12) is quite slender and, though incomplete at the upper end, was evidently quite short. The spine is curved forward, so that it lay close to the spine of the axis, and its base is quite narrow, as it is sharply pinched in by a deep fossa on each side. The anterior and posterior zygapophyses are well developed, and the faces are nearly horizontal, so that in the natural condition of the bone they looked straight up and down. The transverse process was attached to the base of the neural spine and to a ridge rising from the upper portion of the centrum; the lower end of this ridge is supported by slight ridges running toward the anterior and posterior faces of the centrum. These last ridges assume considerable importance in the more posterior vertebræ. The transverse process is present on the vertebræ, but broken from position and displaced somewhat to the rear. It has been figured in outline in its proper position, so that the nature of the posterior portion of the vertebra may be seen, but the dimensions and form are correct as figured. The process starting from the base of the spine decurved rapidly, and its distal face reached to the lower edge of the centrum. The notochordal portion of the centrum is confined to the upper half, and the lower is occupied by a narrow and prominent keel. The posterior face is somewhat lower than

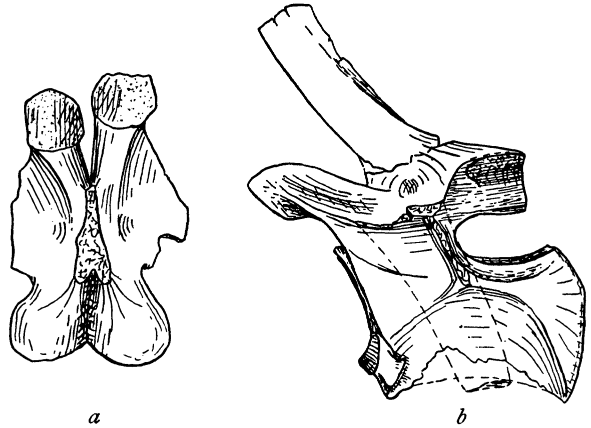

FIG. 12.—Third cervical. *a*, from above; *b*, from the side. ⅔ natural size.

the anterior, but this is not so pronounced as in the axis. The lower half of the anterior face is a flat surface, to which is still attached the intercentrum. This is crescentic in shape and rather broad on the lower face. On either side there are two prominent processes for the capitula of the ribs. Without the intercentrum the profile of the anterior face would be very similar to that of the axis.

MEASUREMENTS OF THE THIRD CERVICAL.

Length along bottom line of the centrum	0.038^{m}
Width posterior zygapophyses (somewhat crushed)	0.033
Horizontal diameter of posterior face of centrum	0.028
Vertical diameter same	0.028
Horizontal diameter anterior face	0.024

The *fourth cervical* is less well preserved than the third or fifth, and presents no great difference from the third. The transverse process is very wide, the width being due to a very thin extension of the anterior edge; this character persists through the anterior dorsal vertebræ. The ridges supporting the transverse process upon the centrum become very prominent running to the anterior and posterior edges of the centrum; these, with the prominent keel on the lower line of the centrum, form three very prominent ridges on the centrum about equally distant from each other. As in the third, the base of the spine is pinched by the deep fossæ on each side of its base.

MEASUREMENTS OF THE FOURTH CERVICAL.

Length along the bottom line of the centrum	0.038^{m}
Width of posterior zygapophyses	0.032
Horizontal diameter of anterior face of centrum	0.024
Vertical diameter same (including face for intercentrum)	0.028

The *fifth cervical* (Fig. 13) differs from the preceding in the greater relative width of the pre- and postzygapophyses. This may be due in part to crushing of the preceding vertebræ, as the fifth is almost free from distortion, though not entirely so. The distal end of the transverse process is missing, but the whole process was inclined somewhat more to the rear than in the anterior cervicals. The ridge rising from the upper portion of the centrum and supporting the lower edge of the process is still present but is shorter. The transverse process is rising from any contact with the centrum to a position on the base of the neural arch. The intercentrum is in position and is similar to the earlier ones. The keel on the lower edge is very thin and sharp and of considerable vertical extent. The posterior face of the centrum is no lower than the anterior. The base of the spine is still very thin, so that the spines probably were not greatly elevated.

MEASUREMENTS OF THE FIFTH CERVICAL.

Length along the bottom line of the centrum	0.032^{m}
Width of the posterior zygapophyses	0.043
Width anterior zygapophyses	0.039

The *sixth cervical* differs from the others in the relative shortness and the greater height of the centrum. The transverse process rises from the upper portion of the neural arch and is well above the neural canal and the centrum; the ridges on the centrum which supported the transverse process have lost connection with it and are present as rudiments which are evidently disappearing. The transverse process curves downward close to the centrum and trends very slightly to the rear; the lower end does not extend below the lower edge of the centrum. This is the first of the vertebræ posterior to the axis in which the intercentrum is not attached, but from the size of the articular space on the lower edge of the anterior face of the centrum it is evident that it was as large as the others and that its displacement is accidental. The articular faces of the zygapophyses are horizontal, and the keel on the lower portion of the centrum is very thin and prominent.

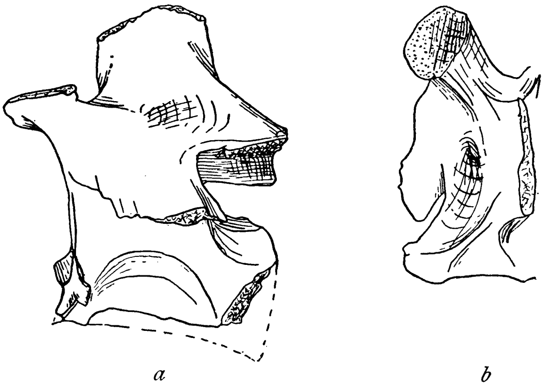

FIG. 13.—Fifth cervical. *a*, from above; *b*, from the side. ⅔ natural size.

MEASUREMENTS OF THE SIXTH CERVICAL.

Length along bottom line of the centrum	0.029^{m}
Height of centrum from bottom to bottom of notch beneath post-zygapophyses	0.030
Width post-zygapophyses	0.040
Vertical and horizontal diameters of the posterior face of the centrum	0.033

The *seventh cervical* (Fig. 14) has the centrum relatively higher and shorter than the preceding, and the keel is much more prominent. The edge of the keel forming the lower edge of the centrum is nearly straight. The intercentrum is absent, and the recurving of the lower portion of the edge of the anterior face in forming the face for the centrum shows very prominently the "twisted" appearance described by Cope. The transverse process rises from the neural arch quite above the neural canal and the centrum and decurves close to the side of the centrum. There is no trace of the ridges which supported the transverse process on the centrum in the anterior vertebræ; its distal end does not reach below the lower edge of the centrum. The trans-

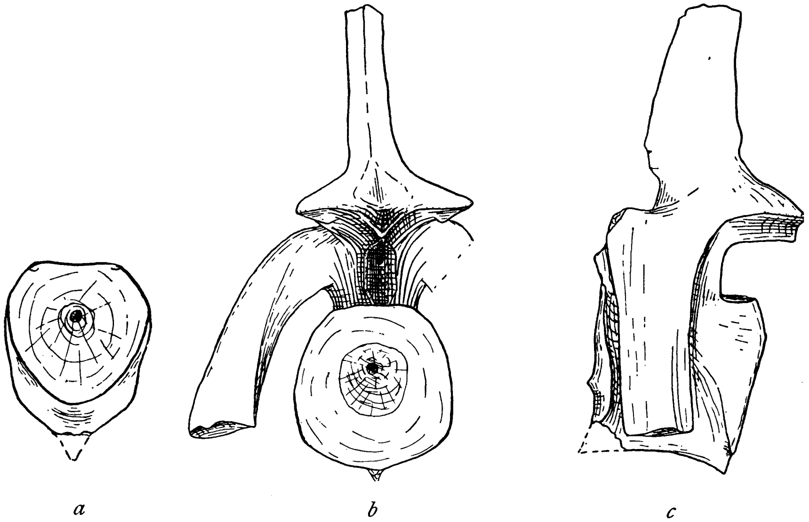

FIG. 14.—Seventh cervical.—*a*, anterior face of the centrum; *b*, posterior view of vertebra; *c*, side view. ⅔ natural size.

verse process lacks something of the thin plate extending from its anterior edge which gives it the very broad appearance in the anterior cervicals and it is much stouter. In this vertebra for the first time the suture between the neural arch and the centrum is quite evident. On the upper edge of the anterior face of the centrum near the sides are small prominences seemingly articular in nature, but I can find no corresponding structure on the posterior faces of any of the vertebræ. The base of the neural spine is much stouter than in the preceding vertebra, and the spine was probably much more elevated.

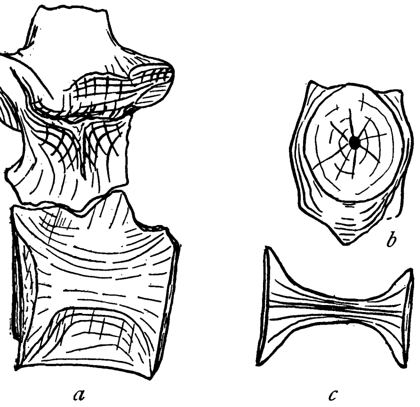

FIG. 15.—An anterior dorsal vertebra, the twelfth of the restoration. *a*, from the side; *b*, anterior face of the centrum; *c*, profile of the centrum from below. ⅔ natural size.

MEASUREMENTS OF THE SEVENTH CERVICAL.

Length along the bottom line of the centrum	0.029^{m}
Height of centrum as in the sixth	0.032
Horizontal and vertical diameters of the posterior face of the centrum	0.030
Width of the post-zygapophyses	0.033

The next vertebra (Fig. 15) probably belongs farther back in the series. It is the twelfth of the restoration. The numbers used below are those of the restoration. This vertebra is typical of the dorsal series. It differs markedly from the vertebræ described as cervical, and not least in the fact that the neural arch and spine are separate from the centrum. The centrum is more high than long, and the keel is very prominent, forming at least half of the vertical extent of the centrum. The transverse process rises from the base of the neural spine and probably extended almost straight outward (this is true in *Dimetrodon*). The distal end of the transverse process is missing, but the base even rises slightly after leaving the spine; at this point the process is very thin vertically and quite broad in an antero-posterior direction. The base of the transverse process rises from three ridges, two rising from beneath the anterior and posterior zygapophyses and a third vertical ridge on the side of the neural ral arch. The base of the spine is quite broad and strong. The spine was elevated. The pre- and postzygapophyses differ from the cervicals in that their antero-posterior diameter is relatively much less and the articular faces are no longer horizontal, but inclined outward as well as downward and inward as well as upward.

MEASUREMENTS OF THE TWELFTH VERTEBRA.

Length along the bottom line of the centrum	0.025^{m}
Horizontal diameter of the posterior face of the centrum	0.028
Vertical diameter same	0.029
Antero-posterior extent of zygapophyses	0.040
Width of anterior zygapophyses	0.030

The *thirteenth* to the *sixteenth* vertebræ, inclusive, are very similar to the twelfth, and all belong in the dorsal series; the notable point is the gradual elongation of the centrum so the antero-posterior diameter becomes greater than the vertical. The neural arches are detached in all the dorsal vertebræ, but in the seventeenth the arch lies near the vertebra and shows that the character of the articular faces of the zygapophyses gradually change so that they are becoming more and more horizontal. The base of the neural spine is very broad, but there is a deep pit on either side. The anterior face of the centrum shows an articular face for an intercentrum. In Fig. 10 *c* is shown an intercentrum, probably from this region. It is noticeably smaller than the intercentra from the anterior portion of the column, and the faces for the capitula of the ribs are very small and are not supported on tubercles.

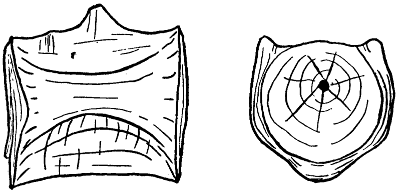
a *b*

FIG. 16.—A dorsal, the sixteenth of the restoration. *a*, from the side; *b*, anterior face of the centrum. ⅔ natural size.

MEASUREMENTS OF DORSAL VERTEBRÆ.

Length along bottom line of thirteenth	0.0275^m
Length along bottom line of fourteenth	0.0245
Length along bottom line of fifteenth	0.032
Length along bottom line of sixteenth	0.031
Length along bottom line of seventeenth	0.0325
Length along bottom line of eighteenth	0.034

The *nineteenth* vertebra (Fig. 17) is characterized by the diminution of the keel. The lower edge of the centrum is rounded and the keel is indicated by a narrow line only. The anterior face of the centrum is rounded and quite similar to the posterior, there being but a small facet for the intercentrum. The zygapophyses are narrow and nearly horizontal, and the transverse process stood out at nearly right angles to the body of the centrum.

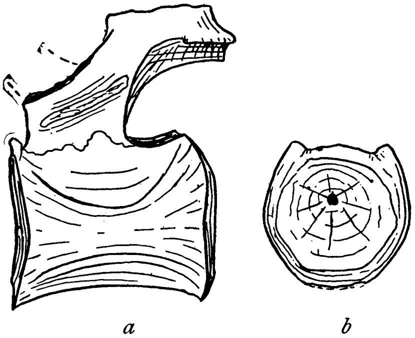

FIG. 17.—A posterior dorsal, the nineteenth of the restoration. *a*, from the side; *b*, anterior face of the centrum. ⅔ natural size.

MEASUREMENTS OF THE NINETEENTH VERTEBRÆ.

Length along bottom line of the centrum	0.035^m
Horizontal diameter of face of centrum	0.029
Vertical diameter of face of centrum	0.028
Vertical height of centrum to base of notch beneath post-zygapophyses	0.029

The *twentieth* to the *twenty-fourth* vertebræ, inclusive, are quite similar to the nineteenth, but show a gradual decrease in length, as shown by the measurements below:

MEASUREMENTS.

Length along bottom line of twentieth	0.036^m
Length along bottom line of twenty-first	0.037
Length along bottom line of twenty-second	0.033
Length along bottom line of twenty-third	0.030

The edge of the anterior face of the centrum of the twenty-fourth vertebra is expanded into a slight face for the capitulum of the rib; it is probable that the main portion of the capitulum was attached to the intercentrum, but we have here the first step in the formation of the type of articulation which is present in all posterior vertebræ. In other respects the vertebra resembles those immediately preceding it; the neural arch is attached to the centrum, but the sutural connection is very distinct. Attached to the spine of this vertebra is one of the intercentra such as is found in the posterior portion of the column. It is broadly crescentic, with but slight curvature, and is of considerable antero-posterior extent on the mid-line. The bone is very thin, and there are no faces for the capitulum of the rib; it is probable that the intercentrum is displaced and belongs farther back in the series. One thing seems very certain: the width of these intercentra is too great to permit their having occupied a position between the vertebræ in the anterior portion of the column, and there are no articular faces for them on the lower portion of the anterior face of the centrum. They must have rather underlain the point of union of the two vertebræ.

MEASUREMENTS OF THE TWENTY-FOURTH VERTEBRA.

Length along bottom line of centrum - - - - - -	0.0285^{m}
Length intercentrum attached to spine - - - - -	0.032
Width of the intercentrum antero-posterior - - - -	0.009

Beginning with the twenty-fifth, the series is complete and in position to the second caudal, so that it is certainly the seventh presacral.

The *twenty-fifth*, seventh presacral vertebra (Fig. 18), has the articular face for the capitular portion of the rib well developed, and the posterior edge of the face is supported by a strong protuberance from the side of the centrum.

Length along the bottom line of the centrum - - -	0.027^{m}

In the *twenty-sixth*, sixth presacral (Fig. 18), the base of the rib is still attached to the vertebra and shows clearly the change in the manner of articulation. The tuberculum is attached to a very short transverse process extending from the side of the neural arch and the capitulum to the articular face formed on the edge of the anterior face of the centrum. The articular face is quite large and stands out prominently from the side of the centrum. The vertebræ are rapidly shortening again and the articular faces becoming relatively larger.

Length along the bottom line of the centrum - - - - 0.026 m

In the *twenty-seventh*, fifth presacral (Fig. 18), the rib seems to have completely lost its connection with the intercentrum. The tuberculum is attached to the downwardly inclined face of a very short transverse process and the capitulum to the edge of the centrum. The capitulum is gradually shortening. The neural spine is rather thin, but has considerable antero-posterior extent. The anterior and posterior zygapoyhyses are nearly horizontal, but the articular faces are somewhat curved.

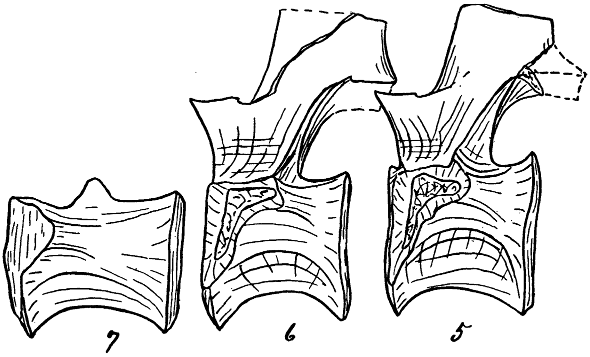

FIG. 18.—The fifth, sixth, and seventh presacrals. ⅔ natural size.

Length of the bottom line of the centrum - - - - - 0.023 m

The remaining presacrals show a considerable similarity. The *twenty-eighth*, fourth presacral (Fig. 19), has the broken base of the rib still attached and show that both tuberculum and capitulum are still present.

In the *twenty-ninth*, third presacral (Fig. 19), the capitulum is much reduced and the rib stands out almost straight from the upper portion of the centrum.

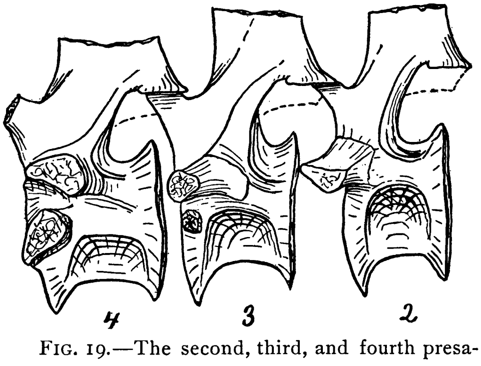

FIG. 19.—The second, third, and fourth presacrals. ⅔ natural size.

In the *thirtieth*, second presacral (Fig. 19), there is no trace of a capitulum, and the rib is a short stubby process.

The *thirty-first*, first presacral (Fig. 20), resembles the preceding in the arrangement of the rib.

As before mentioned the vertebræ are rapidly growing shorter and the last presacral is remarkably shortened. The length of the vertebræ is shown by the measurements given below.

Length along bottom line of the centrum of the twenty-eighth	0.022 m
Length along bottom line of the centrum of the twenty-ninth	0.019
Length along bottom line of the centrum of the thirtieth	0.016
Length along bottom line of the centrum of the thirty-first	0.013
Vertical diameter of the thirty-first	0.039
Horizontal diameter of the thirty-first	0.039

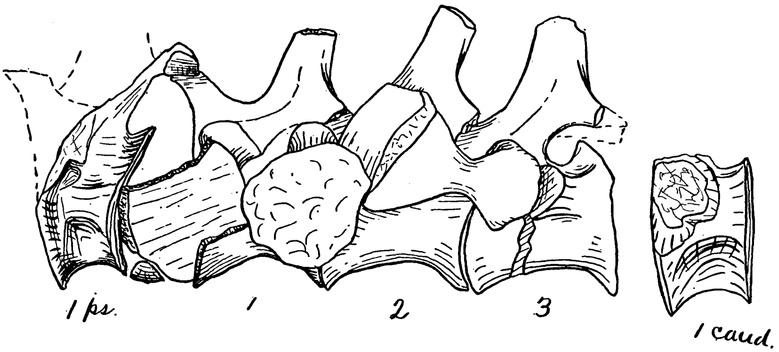

FIG. 20.—Sacral vertebræ from the side with the last presacral and the first caudal. ⅔ natural size.

In the specimen as preserved there is quite a space between the first sacral and the last lumbar, and in this space is a rather large intercentrum. It is quite broad antero-posteriorly and only slightly curved. The lower surface is quite rough, but this may in part be due to accidents of preparation. There is no possibility that there was a space between the vertebræ equal to the width of the intercentrum, so that it must have underlain the line of juncture.

Length of the intercentrum	0.032 m
Width of intercentrum antero-posteriorly	0.014

There are three *sacrals* (Figs. 20 and 21), which differ very markedly from the last presacral and the first lumbar in that they are of considerable relative length. The ribs are attached to the transverse processes and sides of the centrum; as in the lumbars, and are very short, but the distal ends are greatly expanded for attachment to the ilium. The rib of the first sacral extends out almost straight from the sides of the vertebra, but in the second and third the ribs are strongly inclined forward; this is in part due to crushing, but is largely natural, as the articular faces for the proximal ends of the ribs, especially on the third sacral, are inclined forward quite sharply. The sacral vertebræ meet quite closely on the median line below, and there were no intercentra present, but there was no co-ossification. The spines are quite thin, noticeably more so than in the lumbars and first caudals, but of considerable antero-posterior extent; they were possibly not so elevated as the adjacent spines.

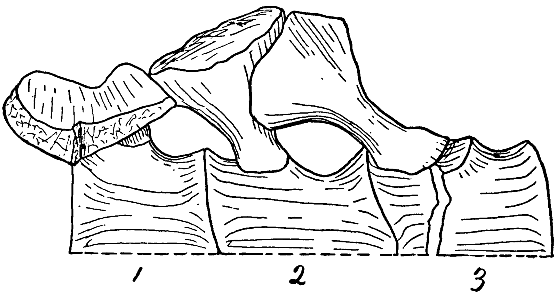

FIG. 21.—Sacral vertebræ from below. ⅔ natural size.

The *first sacral* is somewhat shorter than the others, and the bottom line of all is somewhat concave and is devoid of a keel.

Length along bottom line centrum of first sacral - - -	0.027 m
Length along bottom line centrum of second sacral - -	0.0325
Length along bottom line centrum of third sacral - - -	0.030

The *first caudal* is again short, 0.020 m. Along the bottom line of the centrum it is rather imperfect.

The *second caudal* (Fig. 22), is well preserved. The rib is short and rises much as in the lumbar vertebræ, from the neural arch and from a prominent process on the side of the centrum. The capitular portion extends well down the side of the anterior face. The process on the centrum

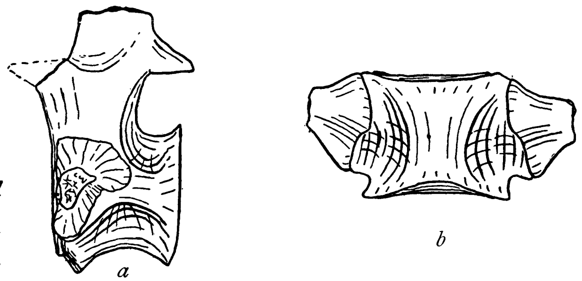

FIG. 22.—The second caudal vertebra. *a*, from the side; *b*, from below.

supporting the capitulum stands out as a rather prominent ridge separated from the obtuse keel of the lower line of the centrum by a deep pit; the whole effect is to give the vertebræ a triangular appearance in section. There are broad intercentra attached to the caudals, but not in position; there is no trace of chevron bones. The lower edges of the anterior faces of the caudals are reflected, making a face for the intercentrum, but those which are found on the vertebræ are too large to have been located between the vertebræ. The whole series of caudals decreases rapidly in size, indicating a short tail.

Length on bottom line of second caudal - - - -	0.0205^{m}
Length on bottom line of third caudal - - - -	0.018
Length on bottom line of fourth caudal - - - - -	0.015

The accompanying restoration is largely from the specimen described above, but some parts have been taken from other specimens, and the ribs have been supplied *in toto* by comparison with the living *Spenodon.* The spines of the vertebræ are largely absent and have been supplied from a specimen of *Dimetrodon* in which the length of the limb bones was almost exactly the same as in the present specimen. The posterior foot has been drawn with Cope's figure of the posterior foot of *Clepsydrops* as a model. The notable weakness of the base of the spines of the sacral vertebræ has suggested that they were in all probability shorter than the others. Four vertebræ have been supplied in the anterior dorsal region, as there is an evident hiatus in the series at that point. The total number of presacral vertebræ is represented as thirty-one, and this cannot be very far from the correct number; this determination is made from the vertebræ of the present specimen and from the figure of the vertebral column of *Dimetrodon* published by Cope.[1] As explained above, this figure probably does not represent the complete column.

The body is drawn somewhat elevated from the ground. At first it seemed probable that the belly was dragged on the ground, but an attempt to place the bones of the fore limb in such a position showed that the relation of the femur to the cotyloid cavity and the head of the radius to the articular

---

[1] *Proc. Am. Phil. Soc.*, August, 1880, Figs. 3 and 3*a*, Pl. VI.

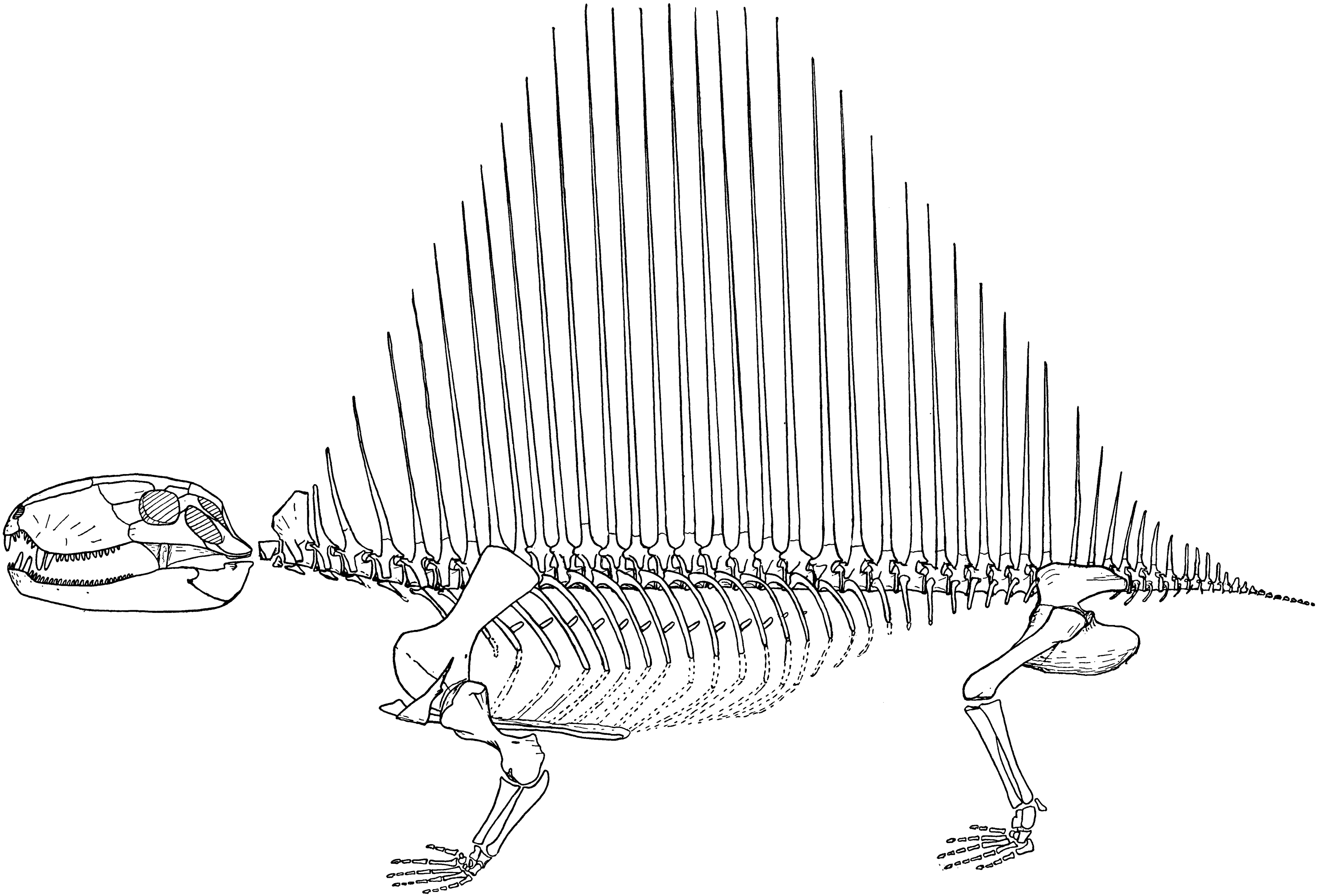

FIG. 23.—Restoration of *Embolophorus*. About 2-9 natural size.

process on the lower end of the humerus would not permit this. The tail would naturally seem to have been pretty long, if for no other reason, than to preserve the symmetry of the animal; but the condition of the caudal vertebræ seems to negative such a proposition. The vertebræ of all long-tailed forms gradually decrease in size and the middle and posterior ones assume the form of simple cylinders. In this specimen the vertebræ decrease rapidly in size and the ones which are only half as large as the first and second are as perfectly formed and as specialized as any in the series.

1. BAUR AND CASE. "The History of the Pelycosauria, with a Description of the Genus *Dimetrodon*." *Trans. Am. Phil. Soc.*, N. S., Vol. XX (1899).

2. E. D. COPE. "Systematic Catalogue of the Species of Vertebrates Found in the Beds of Permian Epoch in North America, with Notes and Descriptions." *Ibid.*, Vol. XVI (1886).

E. C. CASE.

STATE NORMAL SCHOOL,
Milwaukee, Wis.